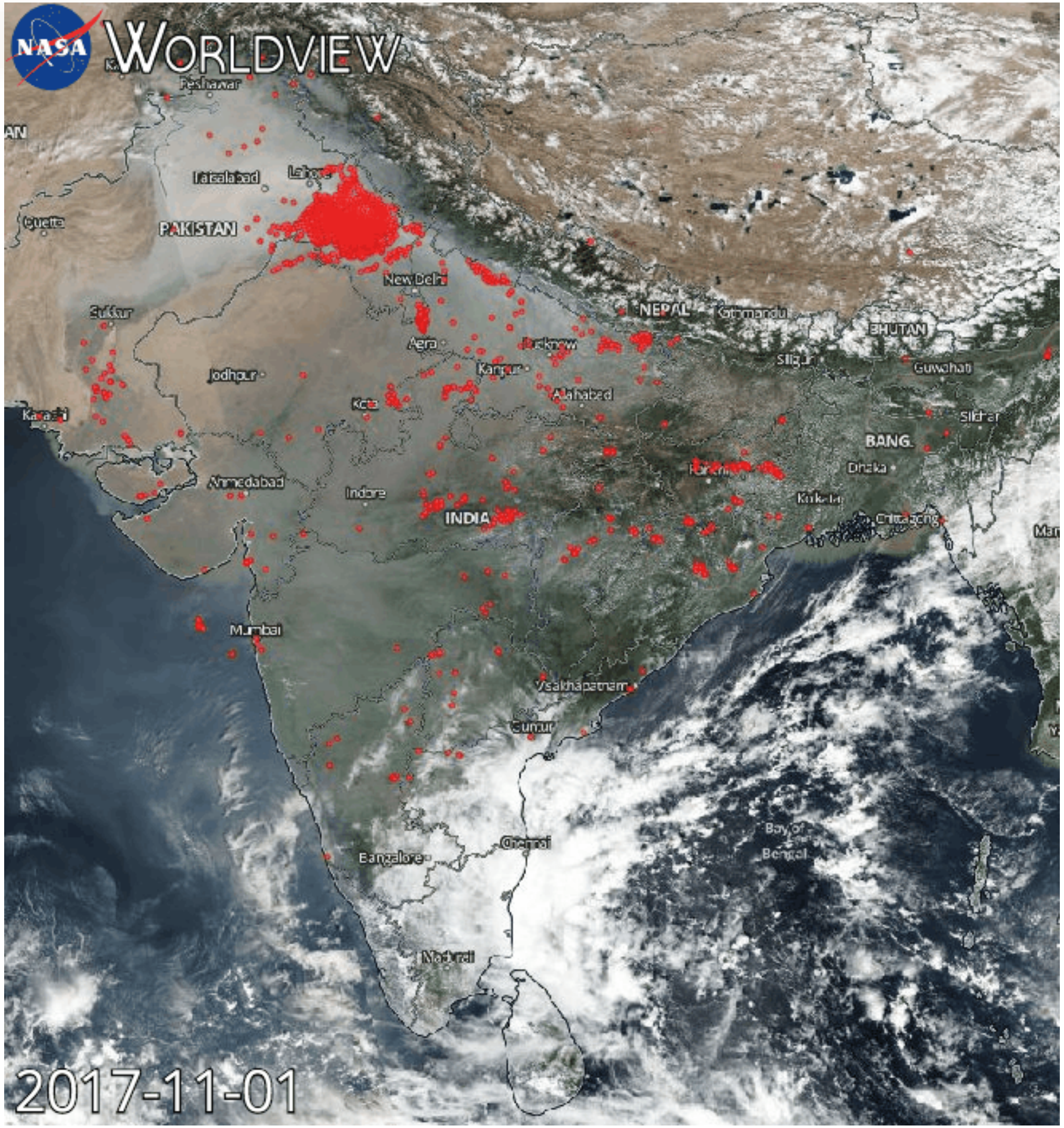


National Aeronautics and Space Administration

Biomass Burning and Aerosol Characteristics in India

<u>Pawan Gupta</u> (STI/USRA at MSFC),
Robert Levy (GSFC),
Anton Darmenov (GSFC),
Falguni Patadia (GESTAR/USRA/GSFC),
Lorraine Remer (UMBC/GSFC), and
Krishna P. Vadrevu (SERVIR/MSFC)

Collaborator: Mukesh Sharma (Indian Institute of Technology, Kanpur, India), Yogesh Kant (Indian Institute of Remote Sensing, Dehradun, India)

MODIS/VIIRS Science Team Meeting, Oct 15-19, 2018, Silver Spring, MD

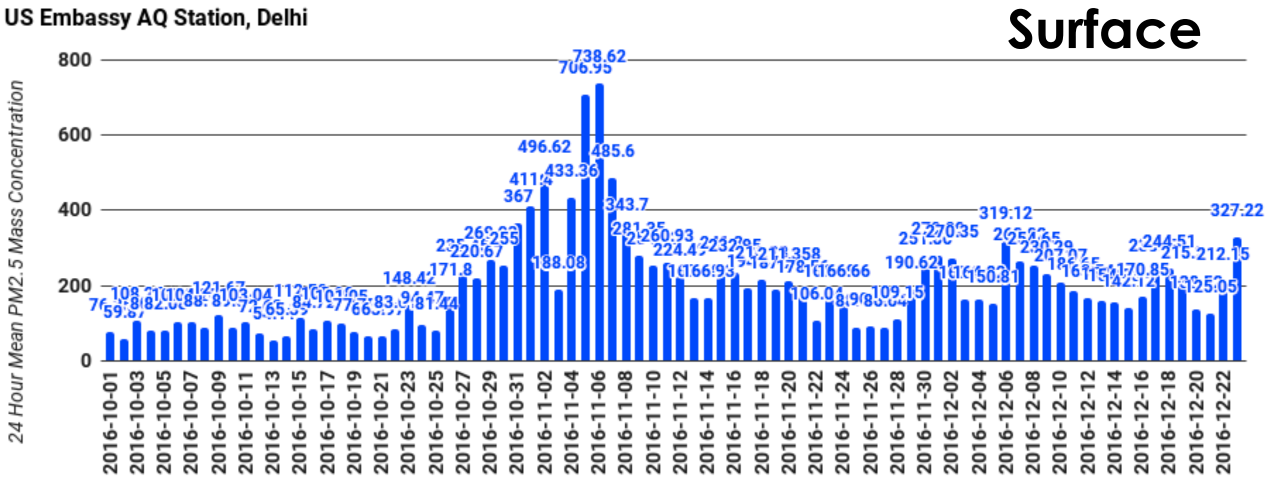
Introduction

Fourteen out of the world's most-polluted 20 cities are in India

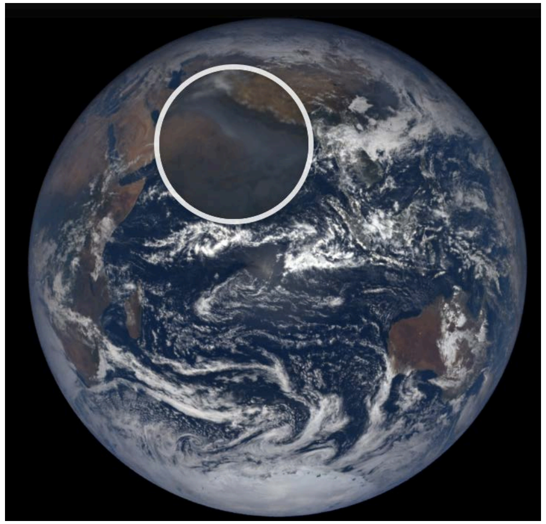
City	*PM2.5	City	*PM2.5
Kanpur	173	Gurgaon	113
Faridabad	172	Jaipur	105
Varanasi	151	Patiala	101
Gaya	149	Jodhpur	98
Patna	144	Baoding	93
Delhi	143	Ulaanbaatar	92
Lucknow	138	Hengshui	87
Agra	131	Xingtai	87
Muzaffarpur	120	Anyang	86
Srinagar	113	Liaocheng	86

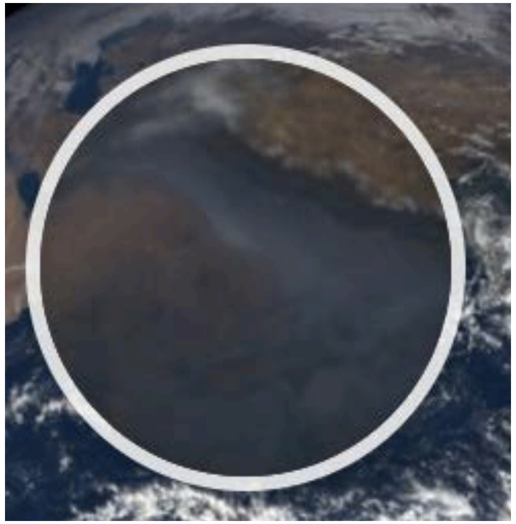
*(Annual mean, ug/m3)

Source: World Health Organization BBC



Can be seen from a million miles away





Four plus decades of research over India

Aerosol Properties

- Photometery aboard rocket
- INDOEX field campaign
- Regional field campaign
- Decadal change in aerosols from satellite

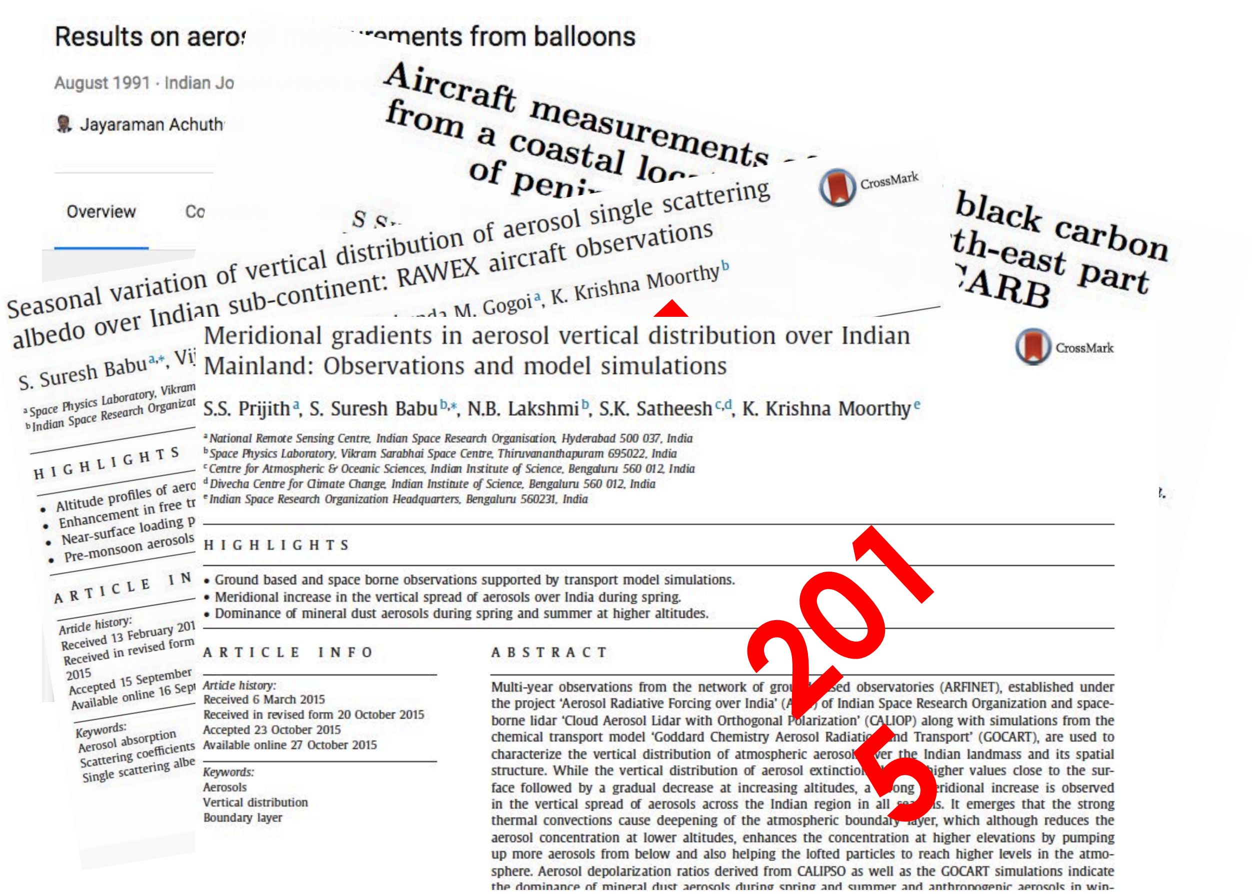
Four plus decades of research over India

Aerosol Properties

Aerosol Sources

Several studies have been published that identify dust , biomass burning , biofuels, vehicular and industrial pollution as dominant sources of aerosols in the region but their relative contribution remain unknown

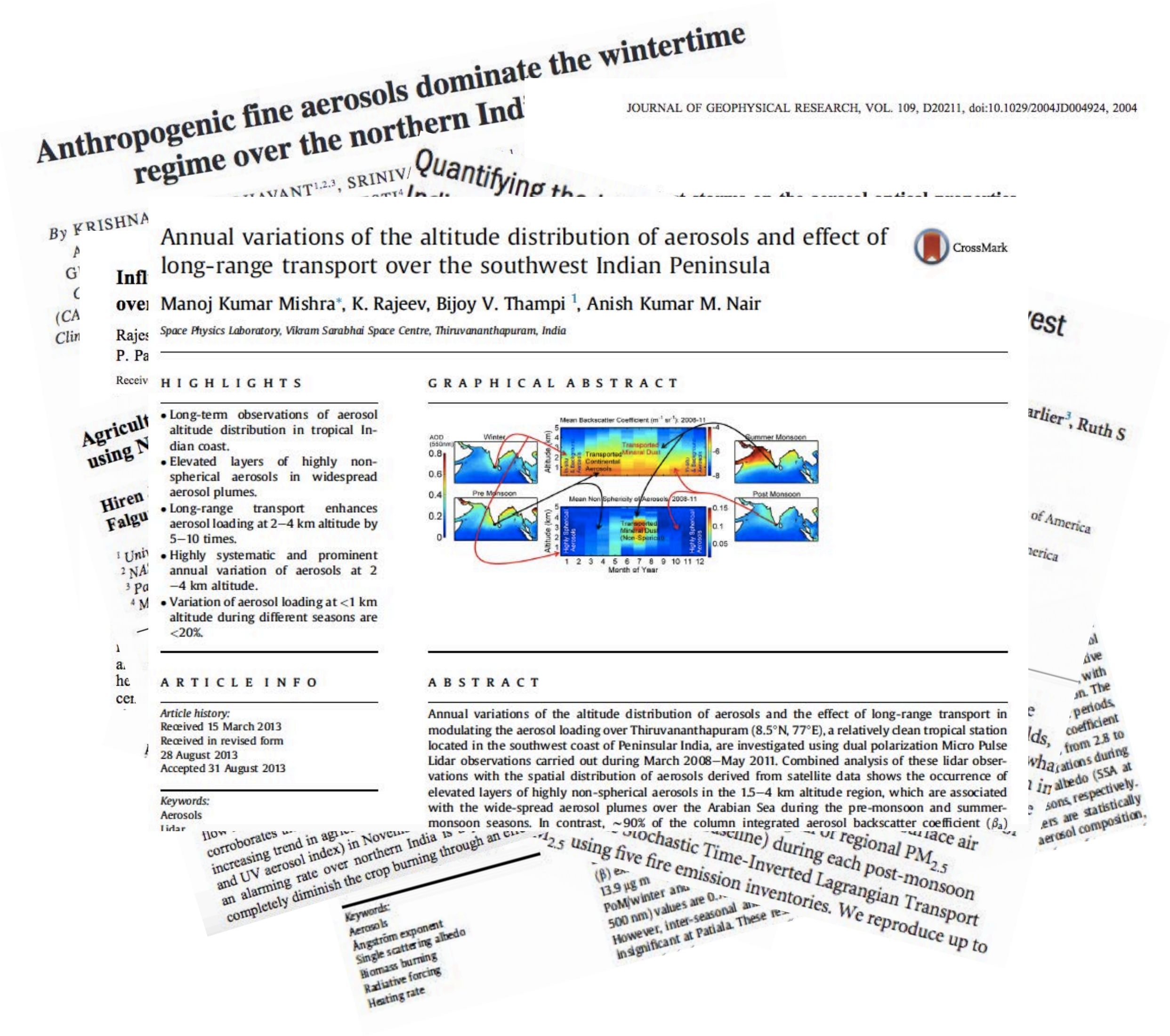
Four plus decades of research over India



Aerosol Properties
Aerosol Sources
Vertical Distribution

Over the year aircrafts have been used to measure vertical profiles of aerosols and its properties along with CALIPSO over last decade

Four plus decades of research over India


Anthropogenic fine aerosols dominate the wintertime regime over the northern Ind

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 109, D20211, doi:10.1029/2004JD004924, 2004

Annual variations of the altitude distribution of aerosols and effect of long-range transport over the southwest Indian Peninsula

Manoj Kumar Mishra*, K. Rajeev, Bijoy V. Thampi [1], Anish Kumar M. Nair

Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram, India

HIGHLIGHTS

- Long-term observations of aerosol altitude distribution in tropical Indian coast.
- Elevated layers of highly non-spherical aerosols in widespread aerosol plumes.
- Long-range transport enhances aerosol loading at 2–4 km altitude by 5–10 times.
- Highly systematic and prominent annual variation of aerosols at 2–4 km altitude.
- Variation of aerosol loading at <1 km altitude during different seasons are <20%.

GRAPHICAL ABSTRACT

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ABSTRACT

Annual variations of the altitude distribution of aerosols and the effect of long-range transport in modulating the aerosol loading over Thiruvananthapuram (8.5°N, 77°E), a relatively clean tropical station located in the southwest coast of Peninsular India, are investigated using dual polarization Micro Pulse Lidar observations carried out during March 2008–May 2011. Combined analysis of these lidar observations with the spatial distribution of aerosols derived from satellite data shows the occurrence of elevated layers of highly non-spherical aerosols in the 1.5–4 km altitude region, which are associated with the wide-spread aerosol plumes over the Arabian Sea during the pre-monsoon and summer-monsoon seasons. In contrast, ~90% of the column integrated aerosol backscatter coefficient (β_a)

Keywords:
Aerosols
Angström exponent
Single scattering albedo
Biomass burning
Radiative forcing
Heating rate

Aerosol Properties

Aerosol Sources

Vertical Distribution

Transport

Focused on spring-summer time dust and postmonsoon smoke transport

Four plus decades of research over India


Declining pre-monsoon dust loading over South Asia: Signature of a changing regional climate

Satyendra K. Pandey[1], V. Vinoj[1], K. Landu[1] & S. Suresh Babu[2]

Desert dust over the Indian region during pre-monsoon season is known to strengthen monsoon circulation, by modulating rainfall through the elevated heat pump (EHP) mechanism. In this context, an insight into long term trends of dust loading over this region is of significant importance in understanding monsoon variability. In this study, using long term (2000 to 2015) aerosol measurements from multiple satellites, ground stations and model based reanalysis, we show that dust loading in the atmosphere has decreased by 10 to 20% during the pre-monsoon season with respect to start of this century. Our analysis reveals that this decrease is a result of increasing pre-monsoon rainfall that in turn increases (decreases) wet scavenging (dust emissions) and slowing circulation pattern over the Northwestern part of the sub-continent.

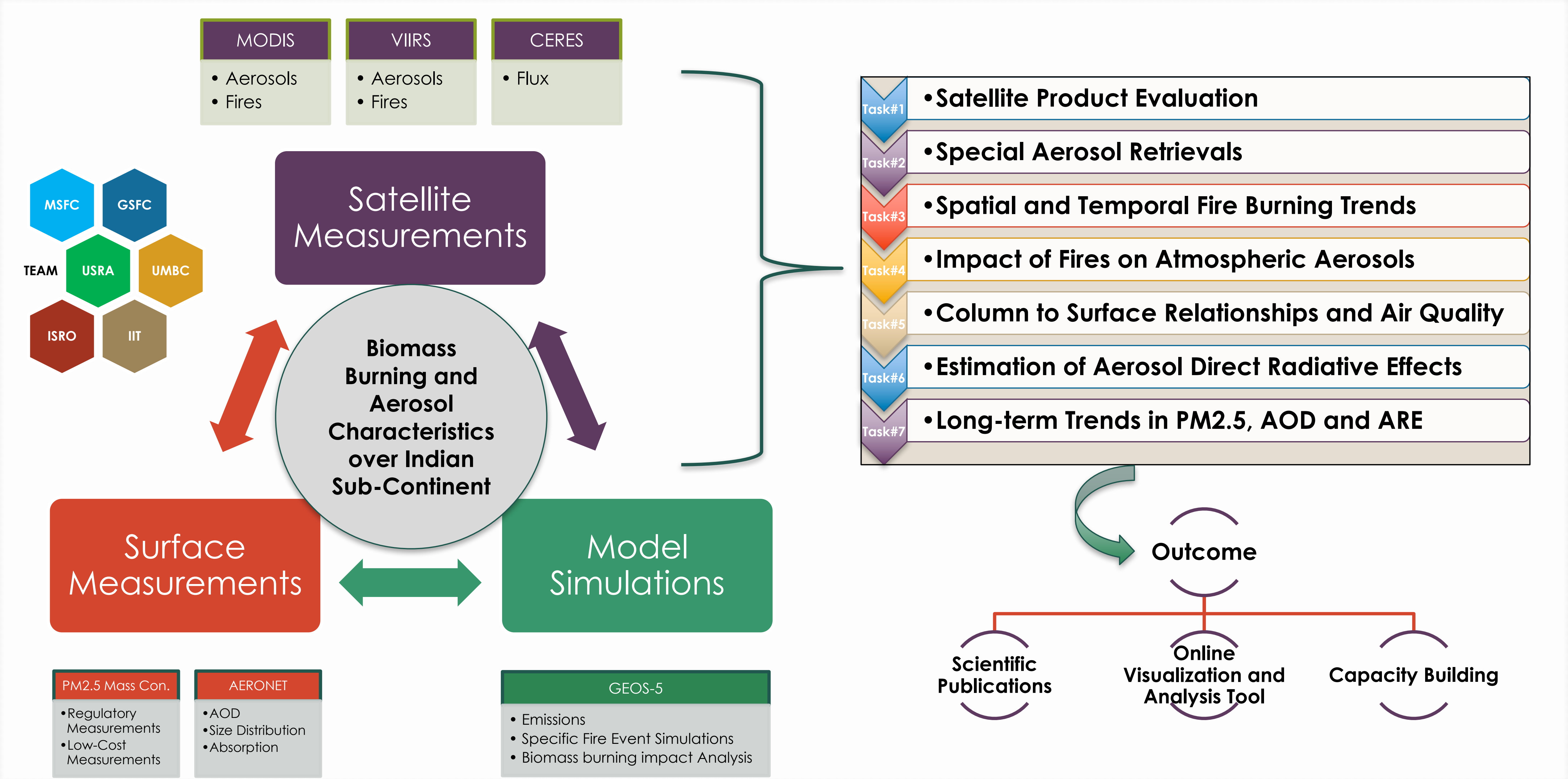
Mineral dust is among dominant natural aerosol species in the atmosphere, besides sea salt[1] and is generated due to wind erosion over arid and semiarid regions of the globe. It affects the Earth system through variety of processes. One such process is scattering and absorption of solar and terrestrial radiation, known as the direct radiative effect[2-4]. Another is by modulating cloud characteristics[5-8], which alters radiative properties of cloud, known as the semi-direct and indirect radiative effects[9,10]. Besides important role in the atmospheric processes, deposition of dust due to long range transport on the glaciers are also found to have profound impact on the planetary albedo[11,12] and hence the radiation budget[13]. Dust also modulates atmospheric dynamics[14-16] through warming within the atmosphere thereby altering circulation patterns. Other than its effect on various components of the climate system[17-20], mineral dust also has many other impacts, such as on marine productivity through nutrient deposition[21], deterioration of air quality by contributing to particulate matter PM2.5[22], on human health by causing acute respiratory diseases[23-26]. The studies in the past have shown that the presence of large absorbing dust in the atmosphere can enhance the lower atmospheric warming[27,28]. For example, it has been shown that Indian summer monsoon rainfall is related to dust loading (both locally and remotely) at different time scales[16,27,29-31].

- Aerosol Properties
- Aerosol Sources
- Vertical Distribution
- Transport
- Impacts

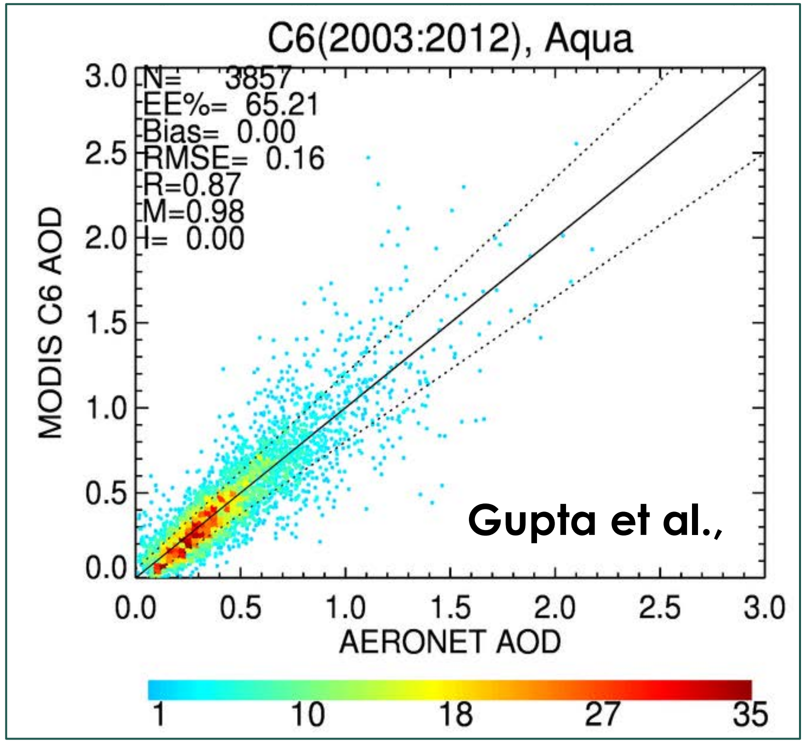
In order to understand the changing nature of aerosols and its implications for AQ and regional radiation budget, continuous monitoring of aerosols is required

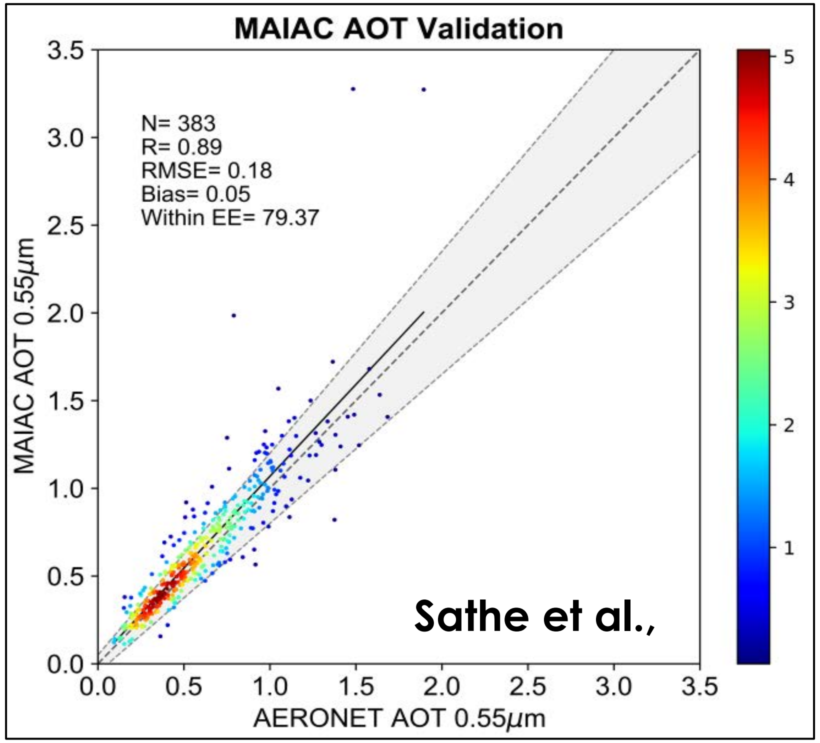
Moving Forward

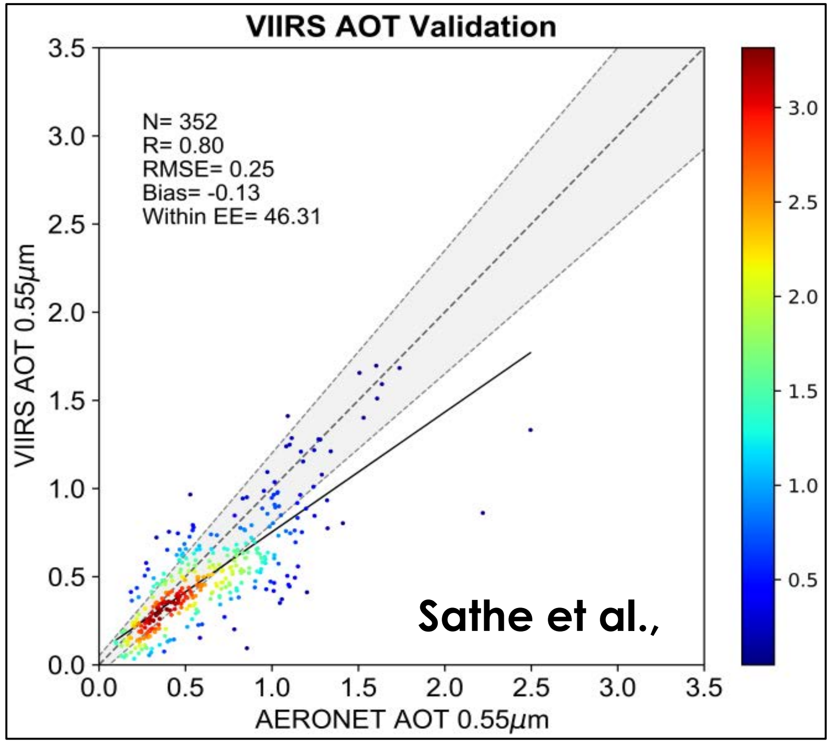
Characterizing Nearly Two Decades of Biomass Burning Over The Indian Sub-Continent Using Satellite, Surface and Model Simulations



Aerosol Data & Validation - India

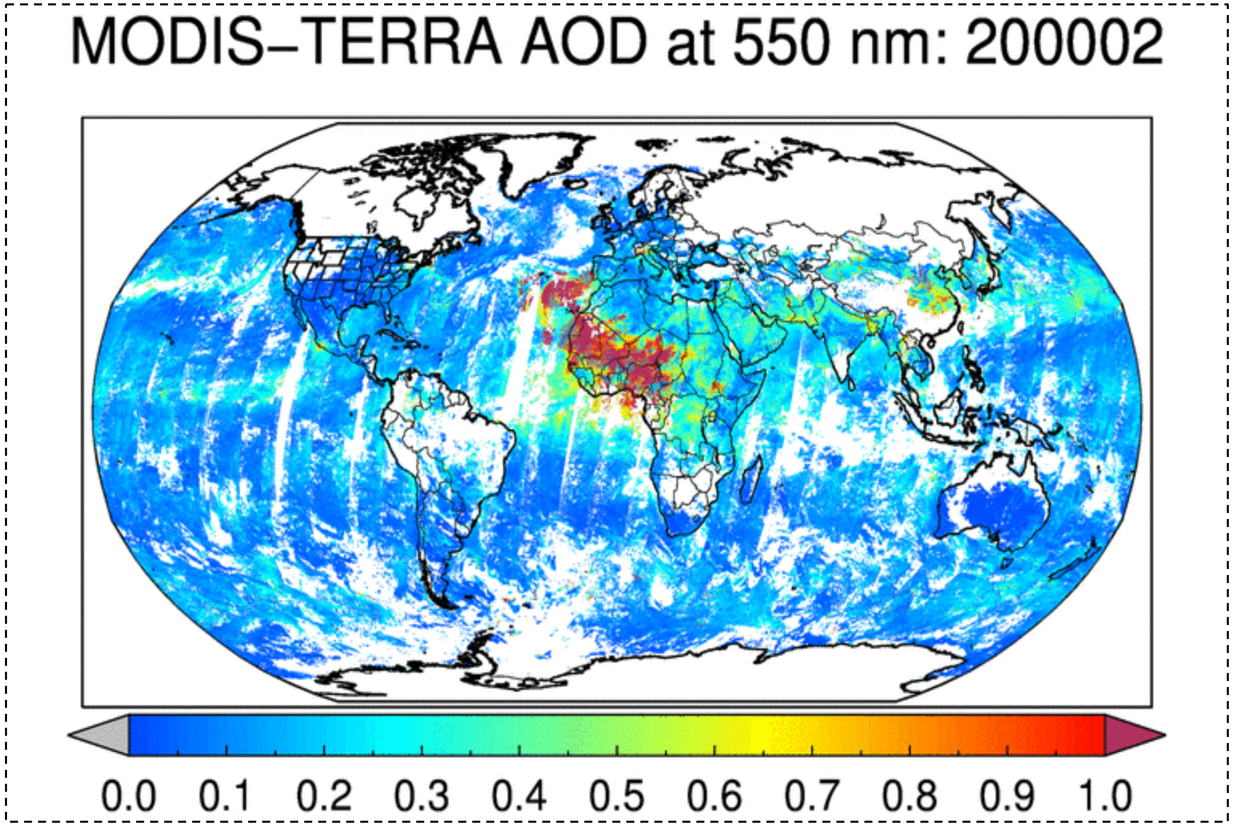


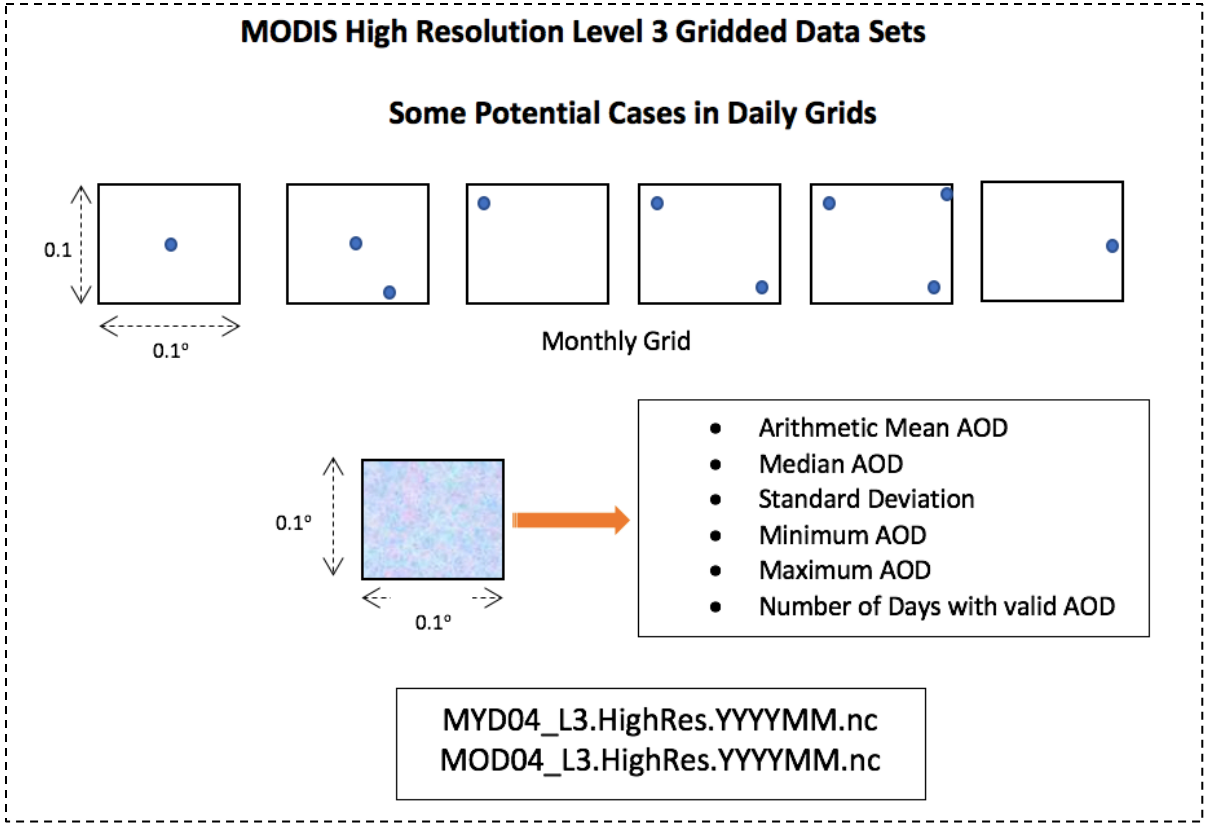




We plan to validate MODIS (DT, DB, MAIAC) and VIIRS (750 m) AODs before using for AQ &Radiative forcing

High Resolution Gridded Product

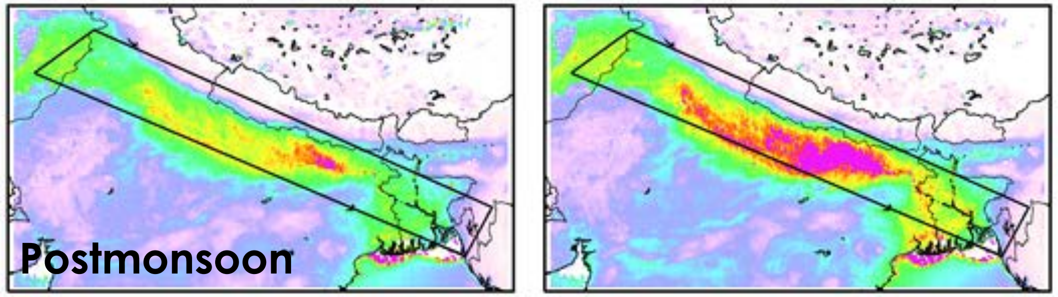




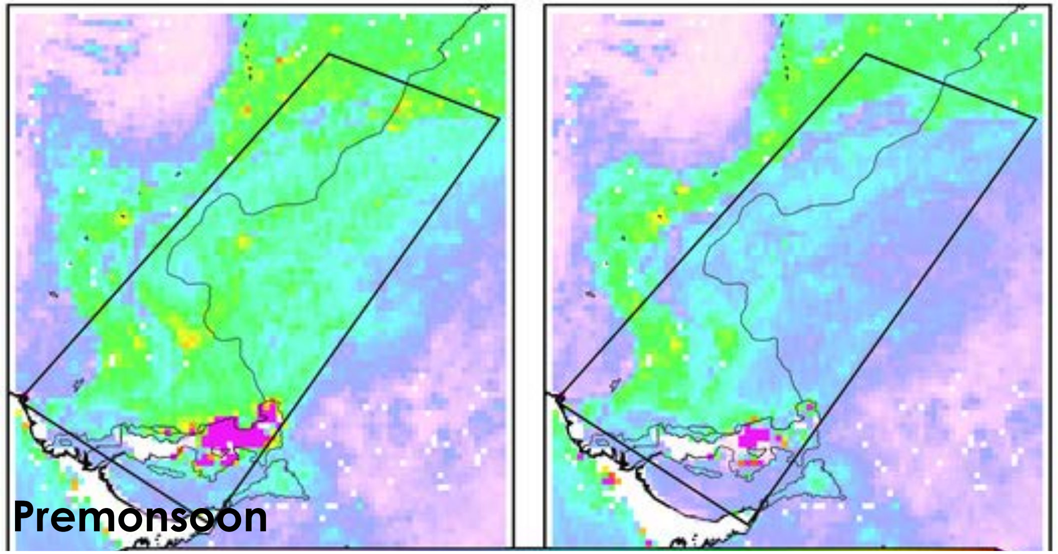
Visualization tool for this data is under development

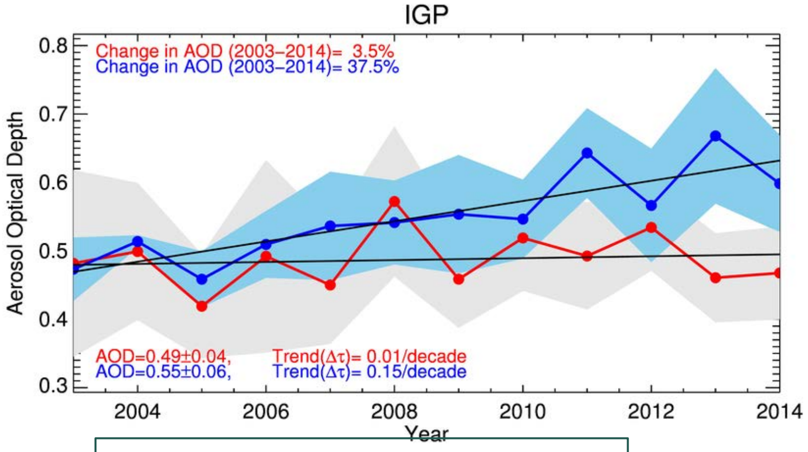
Regional Contrast in Aerosol Trends

2003-2007 **2008-2014**

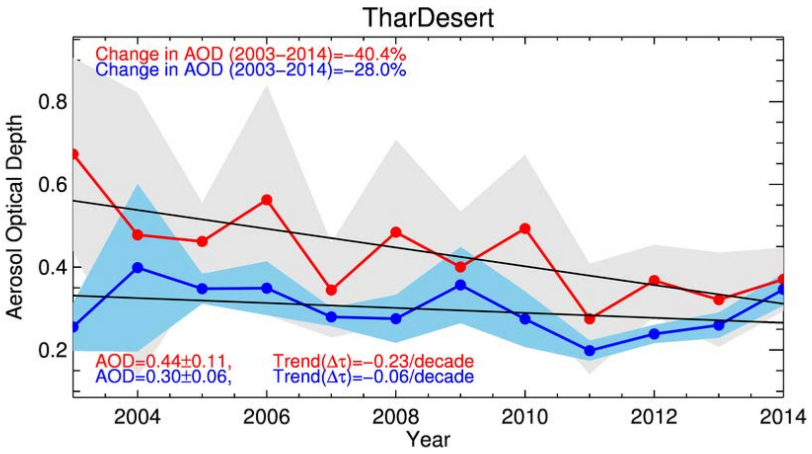


Aerosol Optical Depth at 550 nm



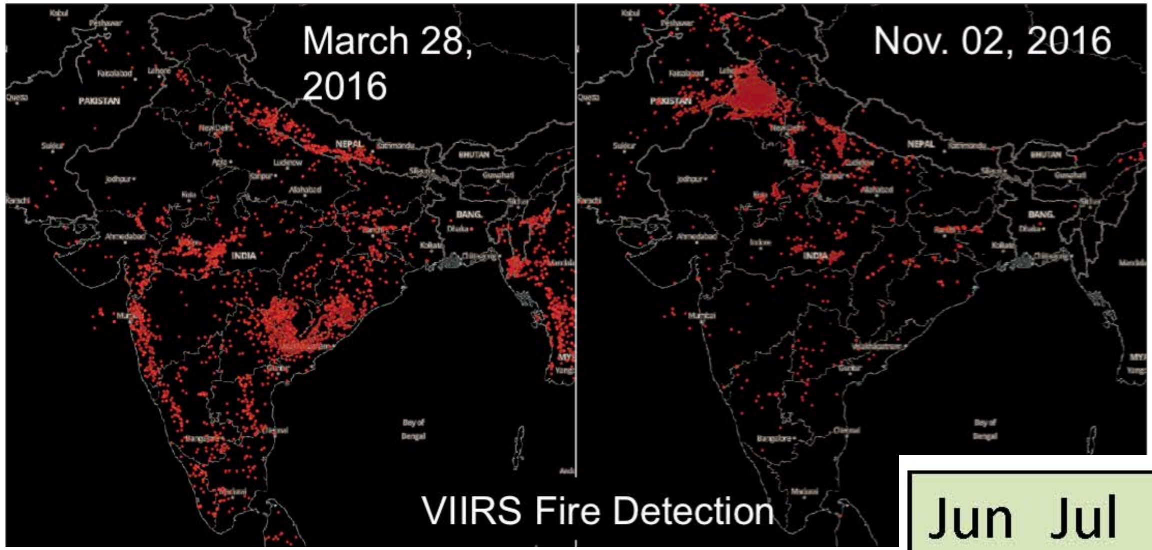


Premonsoon
Postmonsoon



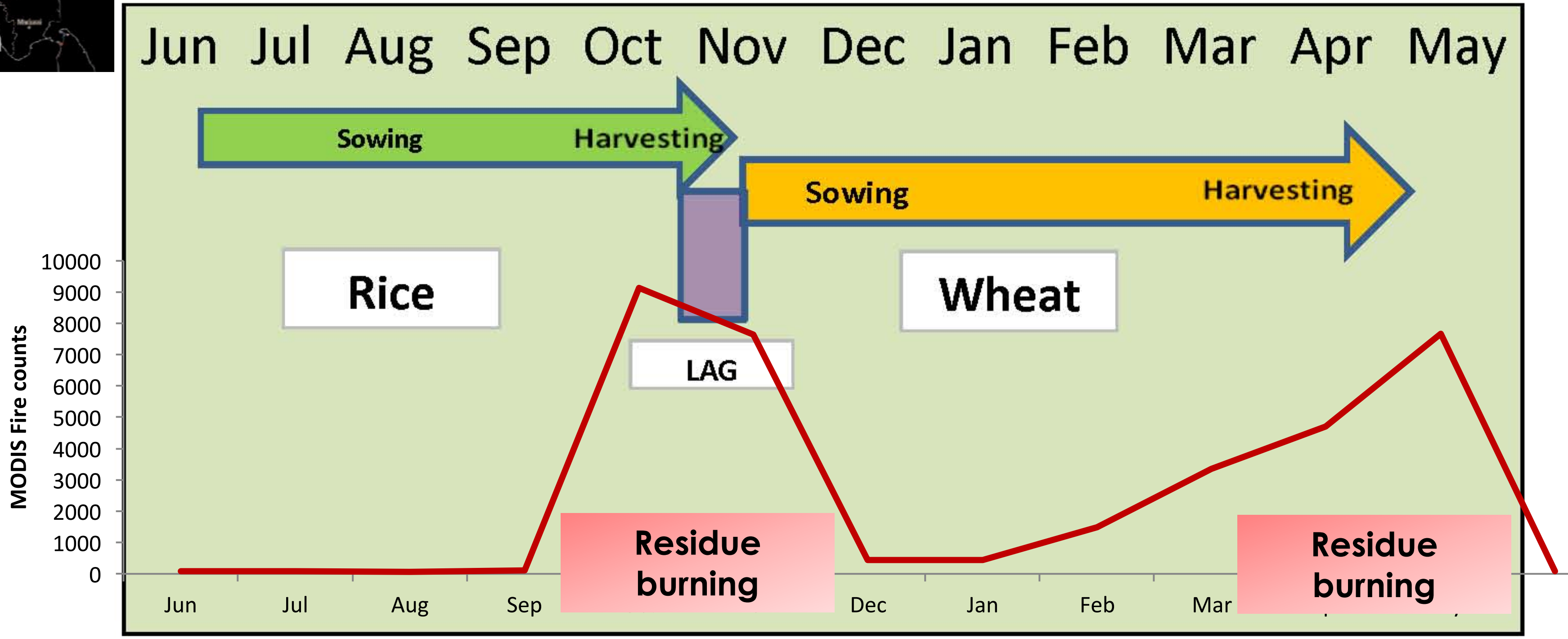
IGP is highly influenced by mineral dust during premonsoon and sea salt during monsoon, while during postmonsoon fine mode aerosols dominate

Seasonal Pattern of Fires



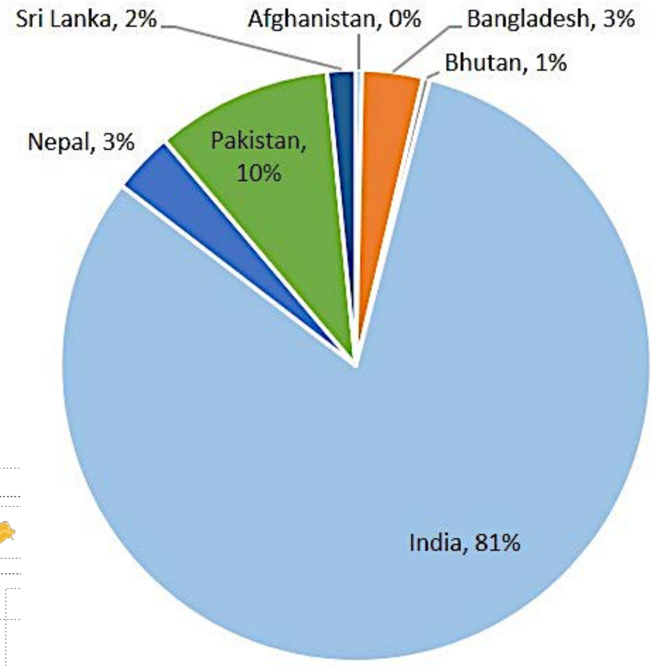
VIIRS fires detected on March 28, 2016 (left) and Nov. 2, 2016 (right). In March we see much burning in central and southern India (agricultural and open fires) and some fires in the IGP and Nepal (forest fires). On Nov 2nd, 2016 the fires have migrated to Northern India, and Pakistan (Image Generated using Worldview).

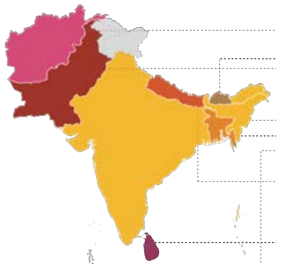
Agricultural fires show bimodal trend corresponding to Rice-Wheat residue burning



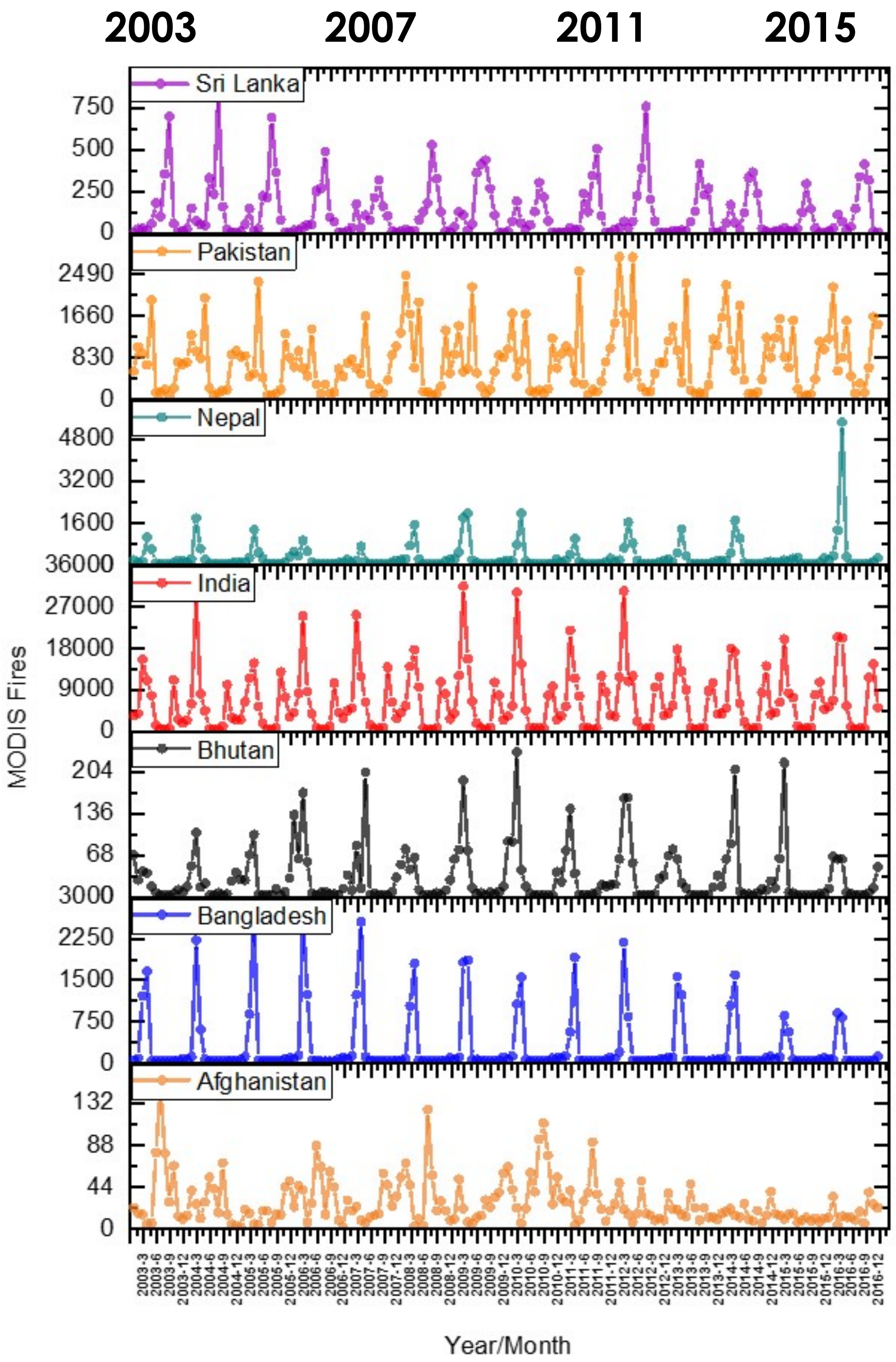
Vadrevu et al., 2011. Env. Pollution

Vegetation Fires in South Asia





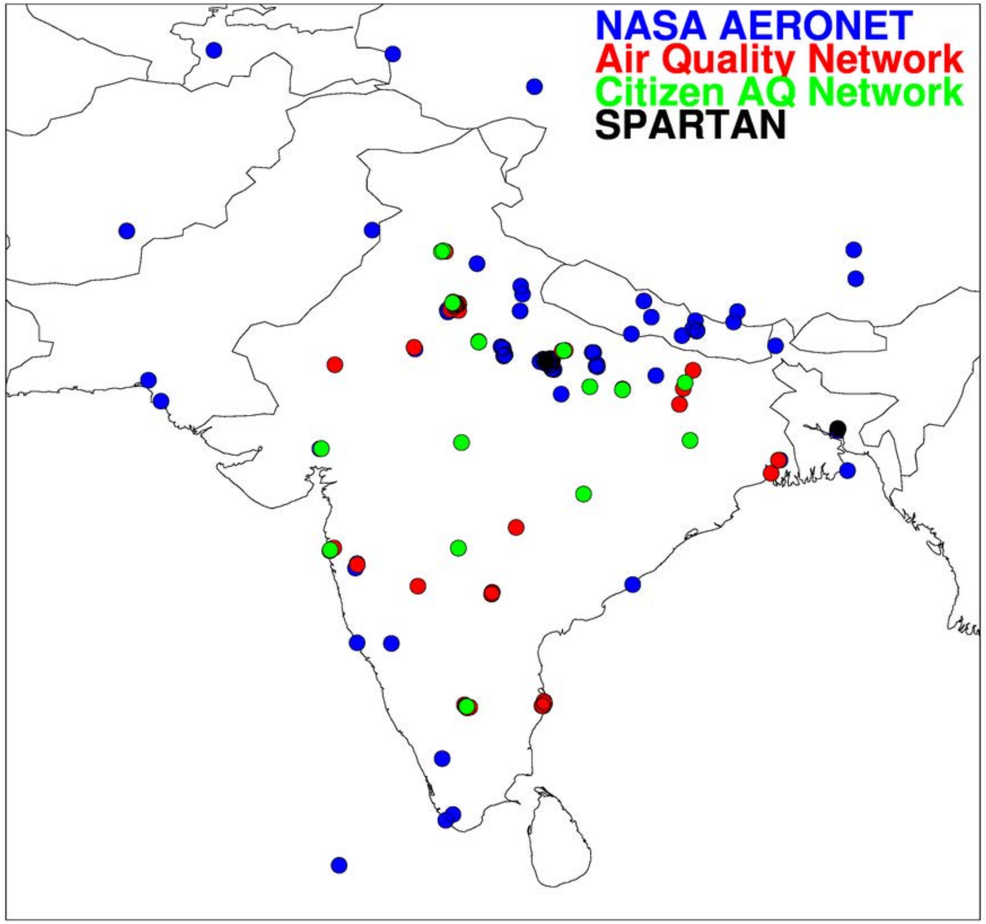
India accounts for 81% of the total vegetation fires in South Asia.



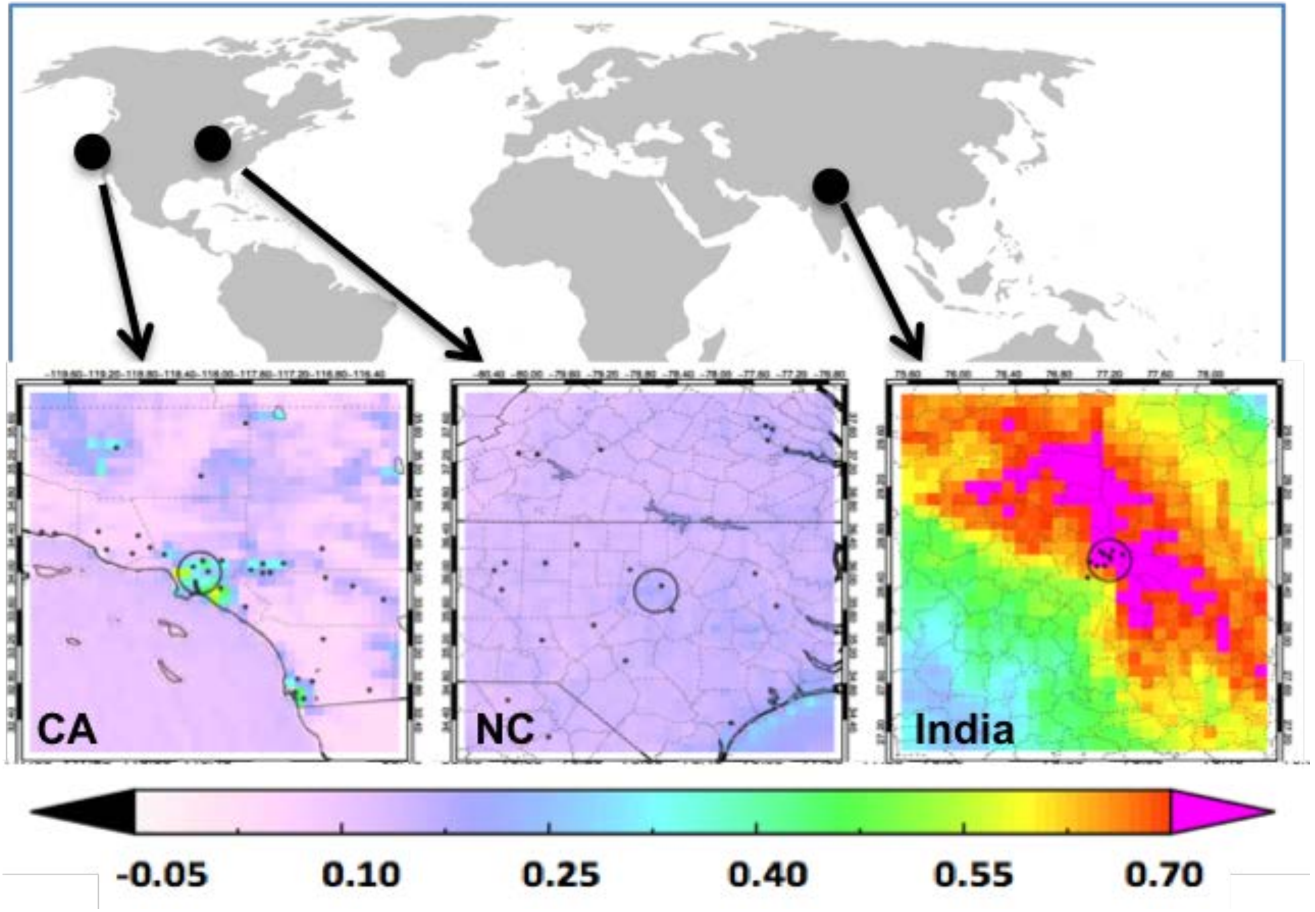
Trends in vegetation fires over different South Asian countries suggests a decreasing trend

(Vadrevu et al., 2018 ERL, submitted).

Surface vs Column

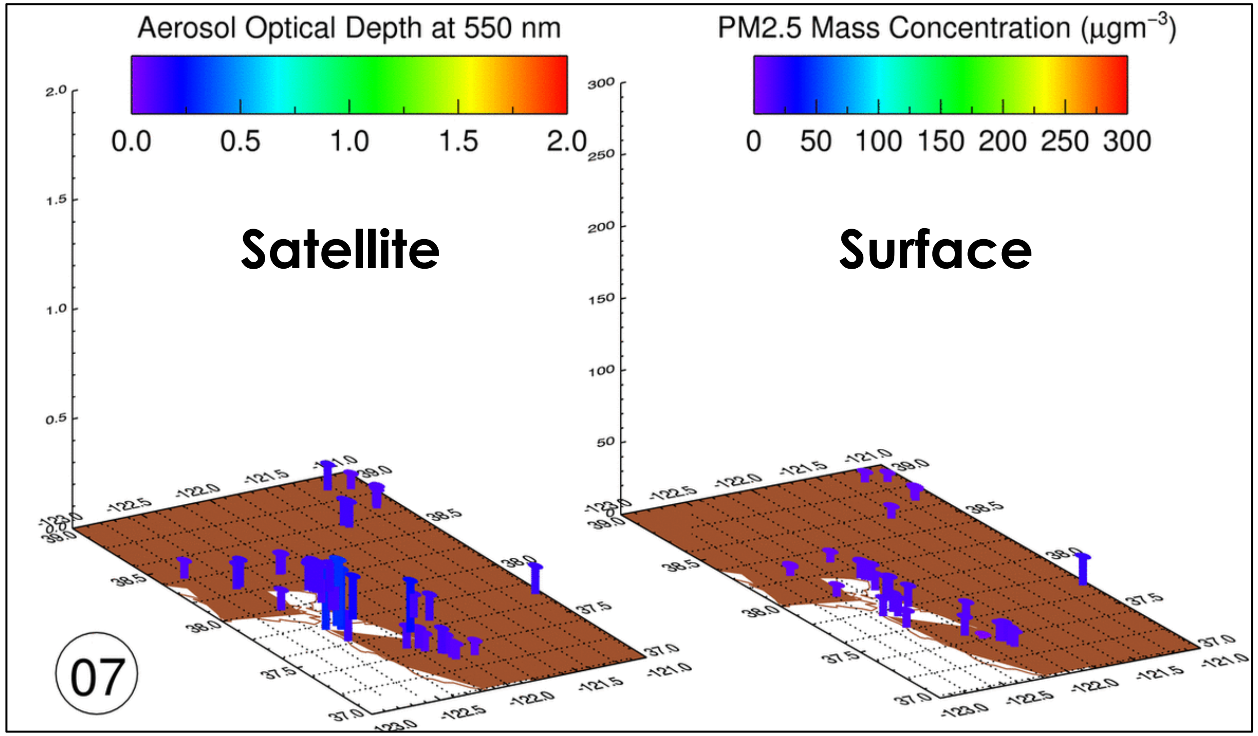


Leveraging NASA Citizen Science Project – Deploying Low-Cost AQ sensors in India



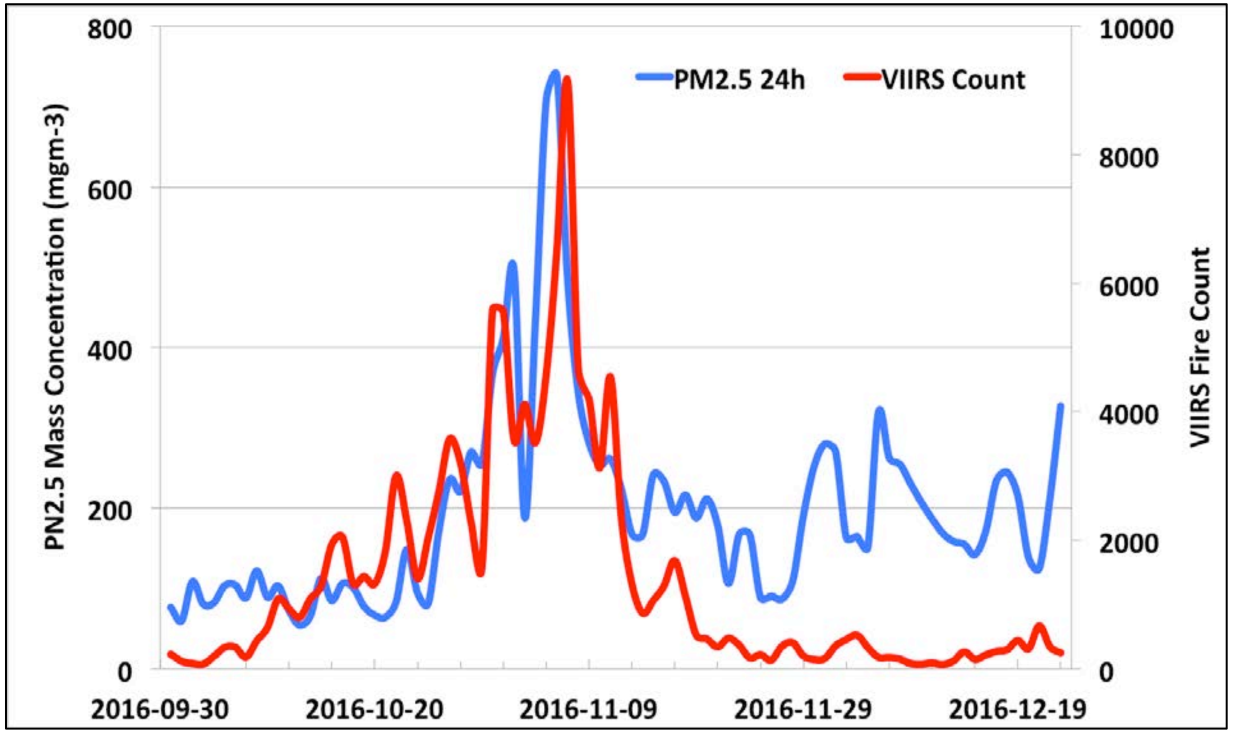
Impact of Biomass Burning on Air Quality

Satellite and Surface Measurements Respond to Change in Air Quality During Fires in CA

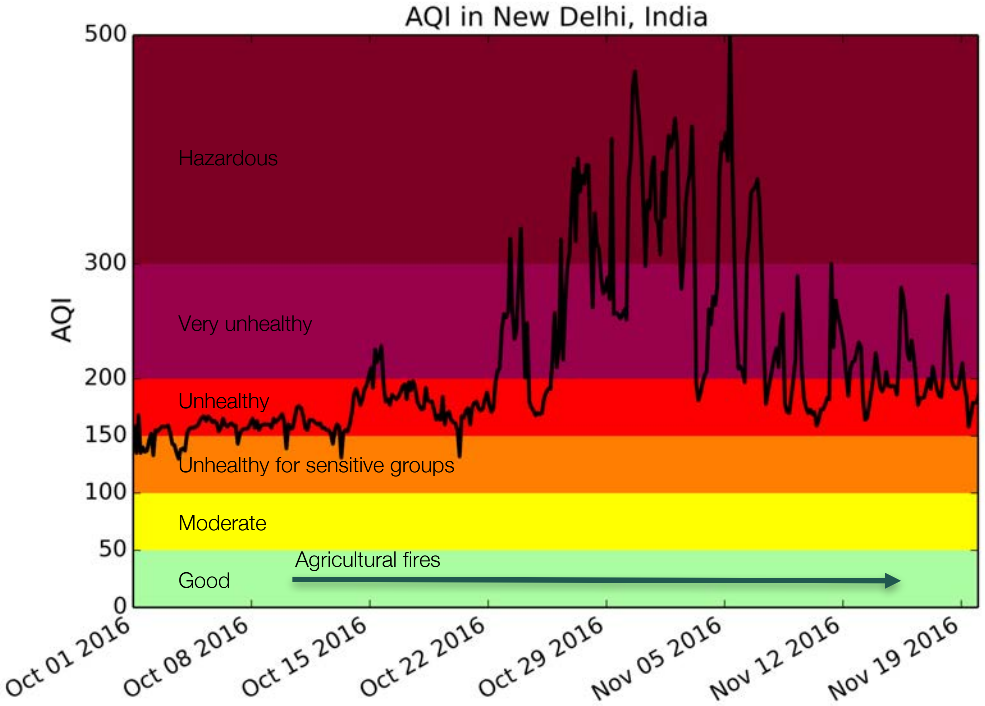


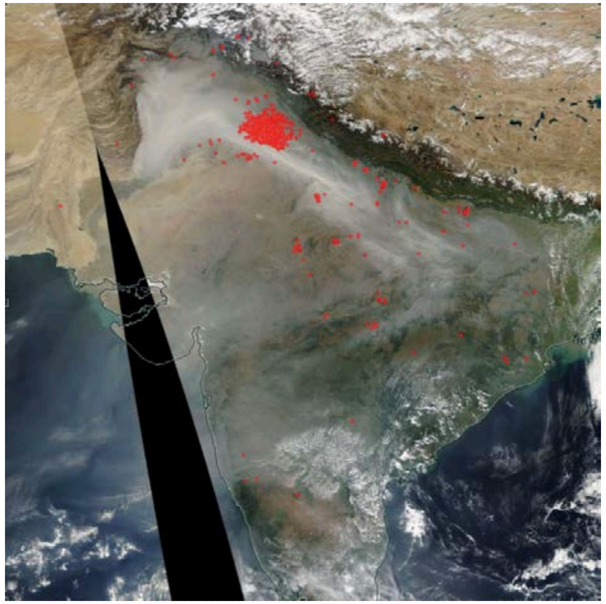
Gupta et al., 2018

VIIRS Fire Counts & PM2.5 – Delhi, India

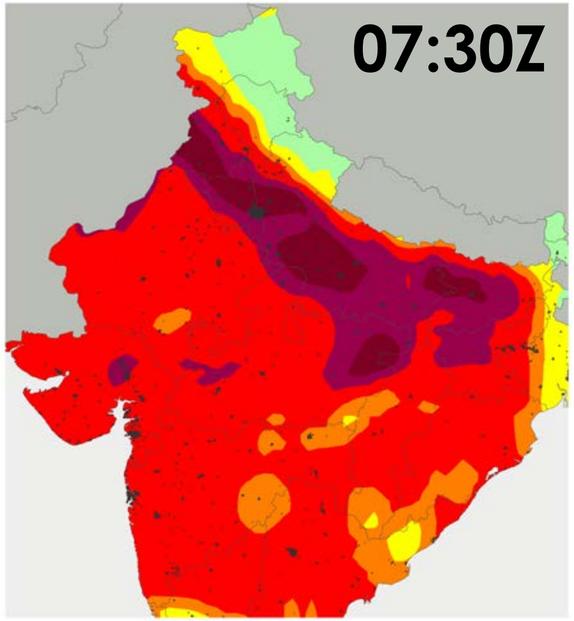


Model Simulation - November 06, 2016





GEOS/FP combined (PM, SO2 and CO) air quality index (AQI)



From; Darmenov et al.,

- **GEOS experiments**
  - **Experiment 1: Full set of emissions**
  - **Experiment 2: No biomass burning emissions**

Goals:

- Estimate contributions due to fires, dust and other sources
- Identify biases in the forward model
- Correct the biases in PM2.5 and find the contribution of the fires to the AQIs

Challenges & Approaches

- Various visual satellite images and correlation analysis suggests the impact of fires on aerosol loading, there is little direct proof.
- during the post monsoon season, aerosols originate not only from crop burning, but also from domestic heating (due to cold temperature) and industrial & vehicular pollution.
- during the spring/summer fire season, dust is added to the mix, which create another layer of complexity and requires a different approach.

  – Long-term background aerosol climatology. This background should include all "normal" particle producing activity, with fires adding an "abnormal" positive perturbation to these values.
  – Explore multiple spectral/spatial tests to identify and retrieve smoke aerosol optical depth
  – CALIPSO climatology of aerosol typing will also be explored
  – Model simulations with improved emission data sets

Summary

- The ISC is suffering from overwhelming burdens of particulate air pollution and creating significant radiative perturbations to the regional and perhaps global energy balance.
- How much of this burden is due to smoke from fires?
- How has the contribution from biomass burning changed over the years?
- How can we inform policy decisions that will begin to mitigate this burden and perturbation?

- With nearly two decades of satellite aerosol and fire detection products, advanced global modeling system, combined with a network of ground measurements in the region, we aim to begin to answer some of these questions.